EXPLORING THE REGIONAL RESPONSE OF THE INTERVERTEBRAL DISC UNDER POSTURAL VARYING LOADS

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INTRODUCTION

This investigation examined differences between the anterior and posterior radial displacement (*i.e.* bulging) of the annulus of the intervertebral disc. Generally, there have been very few studies that have quantified the magnitude of IVD disc bulging on the posterior aspect of the disc. This is attributable to bony structures and passive tissues that occlude a direct line-of-sight to the posterior-lateral region of intact functional spinal units (FSUs). Recent work [1], has characterized the effect of posture on IVD bulging on human lumbar FSUs. With the posterior elements removed, results from this investigation revealed that the median IVD bulge in the anterior and posterior-lateral regions was altered, when a 7.5 Nm flexion moment was applied. However, to the best of the author's knowledge the combined effects of increasing magnitude of compressive load and posture on IVD bulging have yet to be investigated. Therefore, to better understand how the structural responses of the anterior portion of the IVD may be related to the posterior portion, this study quantified the magnitude of anterior and posterior-lateral radial displacement in the IVD across different postural conditions and magnitudes of compressive load. In-line with this objective it was hypothesized that a negative correlation between anterior and posterior bulging would emerge. Results from this study may elucidate a link between radial displacement on the anterior side of the IVD that would facilitate inferences on the structural changes on the posterior side on intact specimens with the posterior element intact.

METHODS

Six cervical porcine FSUs were tested. A modified servo-hydraulic materials testing system was used to apply flexion/extension motion and compressive loading to intact specimens. A 3D non-contact laser displacement sensor (LJ-V7080, Keyence Corporation, Osaka, Japan) was used to measure annulus fibrosus (AF) radial displacement across four levels of compressive load (10 N, 300 N, 600 N and 1200 N) and two posture conditions (neutral and flexion). The anterior aspect of the six FSUs were scanned during all conditions with the posterior elements intact (i.e. anterior-intact condition). Then the posterior elements from these specimens were removed, leaving a reduced FSU. Both the anterior and posterior sides of the IVD were scanned during all remaining conditions (anterior-reduced and posterior). A total of 24 scans (load x4, posture x2, location x3) were collected from each specimen. The primary dependent measure analyzed was peak AF radial displacement across conditions, which was computed from the 3D IVD surface profiles measured using a using a computer-aided bulge analysis software platform produced by the Vision and Image Processing research group, designed to track and quantify AF radial displacement (Version 8.5, Matlab, Mathworks Inc., Natick, MA, USA) (Figure 1).

To facilitate a comparison of peak AF bulging measurements between specimens and to improve anatomical interpretation of the measure, the maximum bulge perpendicular to a vector defined by the endpoints of the superior and inferior endplates has been reported [2]. To determine whether the removal of posterior elements had any effect on the bulge size, a paired t-test was employed to compare the anterior and anterior-reduced AF bulge measurements. A Pearson's r correlation analysis was also conducted on the anterior and posterior AF bulge measurements. Initially, a paired t-test was used to determine if there was a significant difference in the slopes of the posterior-anterior bulge comparisons across magnitudes of compressive load. There was no significant difference that emerged therefore all loading conditions were collapsed into one correlation analysis.

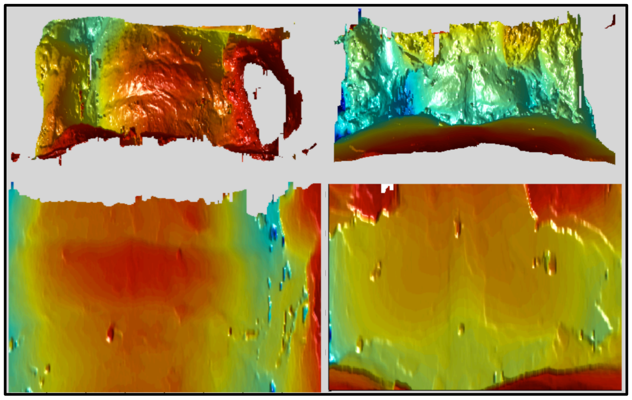

Figure 1: Anterior (left) and Posterior (right) 3D surface profiles of radial displacement measured from the surface of an IVD.

RESULTS AND DISCUSSION

No significant difference was observed between anterior-intact and anterior-reduced peak AF bulge ($p = 0.312$). Therefore, anterior-reduced surface scans were utilized to make comparisons to peak posterior AF bulge. A significant negative correlation between anterior-reduced and posterior bulge measurements was observed in a flexed posture (Pearson's $r = -0.432$; $p = 0.018$). As posterior AF bulging increases anterior AF bulging decreases. (Figure 2).

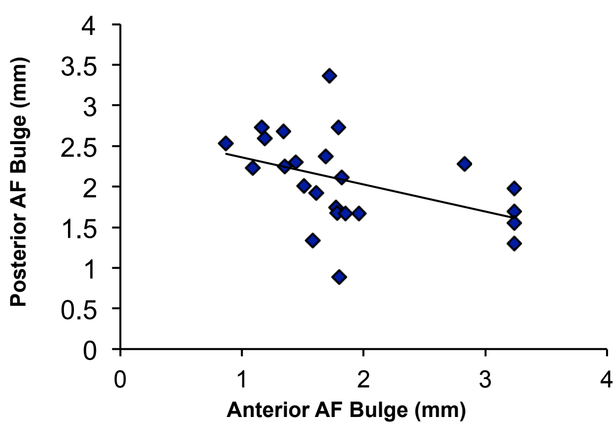

Figure 2: Scatter plot illustrating a negative correlation between anterior-reduced and posterior AF bulging in a flexed posture.

Results also demonstrated that in a flexed posture, as the magnitude of compressive loading increased, there was a trend that emerged of an increased posterior AF radial displacement and a decrease in anterior AF bulge (Figure 3). No significant correlation was observed between anterior-reduced and posterior radial displacement measurements in a neutral posture ($p = 0.312$).

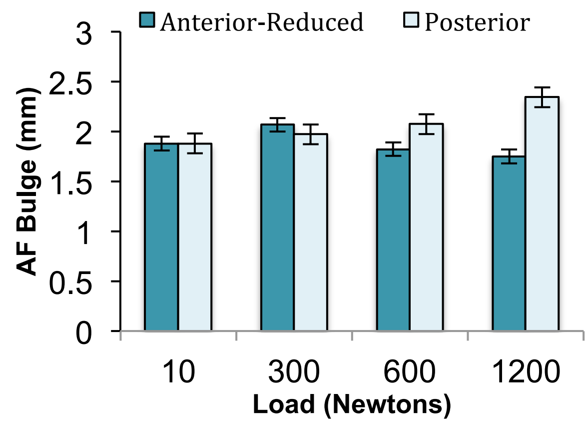

Figure 3: Average anterior-reduced and posterior peak AF radial displacement in a flexed posture across loading conditions. Standard error bars are displayed.

CONCLUSIONS:

The preliminary results from this investigation elucidate a link between measured AF bulge on the anterior and posterior side of the IVD. Understanding how the AF responds under various loads in flexion and extension postures has clinical relevance, as IVD herniation has been observed with repeated flexion-extension under modest amounts of compressive load. The magnitude of posterior AF bulge increased in flexion as the magnitude of the applied compressive load increased. As such, the magnitude of strain and risk of tissue damage in the AF is expected to follow a similar trend.

REFERENCES:

1. Heuer, F et al. (2008b). *J Biomechanics*, **41(5)**, 1086-94.
2. Gooyers, C.E. & Callaghan, J.P. (2015). *J Biomech*, Submitted.